

MAGNETIC SOURCE AND FERROMAGNETIC DEVICE FOR ULTRASONIC WELDING

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention is related to ultrasonic welding devices, and more particularly, to an apparatus for providing pressure to a component during the ultrasonic welding process.

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2) Description of Related Art

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Ultrasonic welding apparatuses are commonly used to join one or more components by producing mechanical vibrations that are absorbed by the component and that heat the material of the component to a melting point and/or to a state where an applied pressure allows the component to be joined. For example, plastics are ultrasonically welded by positioning the plastic component adjacent an ultrasonic horn, through which the ultrasonic vibrations produced by an ultrasonic transducer are transmitted. The plastic component absorbs the ultrasonic vibrations, such that the material plasticizes locally. The plasticized material can therefore be joined to other material. Ultrasonic welding is widely used with plastics because it may be performed relatively quickly and usually produces welds that are relatively free of flash. Ultrasonic welding may also be used with other materials such as metals.

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During the ultrasonic welding process, pressure is typically applied to the component being welded. Such pressure ensures the one or more components are properly joined during the relatively brief period of time that the material is heated. Therefore, applying pressure to the component is an important aspect of ultrasonic welding. However, when components defining unusual shapes or sizes require ultrasonic welding, providing the proper pressure to the component can be complicated. One example of such a component is a rolled sheet being welded into a tube. One technique for providing the proper amount of pressure is to insert a rigid arm into the interior of the tubular component so that the arm applies a pressure on the component proximate the ultrasonic transducer and horn. This technique is often undesirable because of the required amount of fixturing, the difficulty in applying the proper amounts of pressure, the time involved to properly position the arm, and/or the inability of an arm to provide adequate amounts of pressure at hard-to-reach locations

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on the component. Accordingly, a need exists for an apparatus that conveniently provides pressure to a component during ultrasonic welding.

BRIEF SUMMARY OF THE INVENTION

5 The invention addresses the above needs and achieves other advantages by providing an ultrasonic welding apparatus that includes a magnetic source and an associated ferromagnetic device for applying pressure to the one or more components being joined. By providing a magnetic force between the magnetic source and the ferromagnetic device, which are positioned on opposite sides of the component, the 10 ferromagnetic device applies pressure to the component during the ultrasonic welding process.

According to the present invention, the ultrasonic welding apparatus includes an ultrasonic transducer adjacent the component to be joined to another component or to itself. Advantageously, the ultrasonic transducer may include an ultrasonic horn 15 that engages the component during the joining of the component. The ultrasonic welding apparatus also includes a magnetic source that provides a magnetic field and that is proximate the ultrasonic transducer. Advantageously, the ultrasonic transducer and magnetic source are positioned on a common side of the component. The ultrasonic welding apparatus includes a ferromagnetic device on an opposite side of 20 the component from the ultrasonic transducer and magnetic source, such that the magnetic field provided by the magnetic source supports the ferromagnetic device so that the component is positioned between the ultrasonic transducer and ferromagnetic device.

Advantageously, the magnetic field provided by the magnetic source is 25 adjustable so that changes in the magnetic field will change the amount of compressive force the ferromagnetic device applies to the component. Accordingly, while the magnetic source may comprise one or any number of electromagnets, the magnetic source of one embodiment comprises two electromagnets equally spaced from opposed sides of the ultrasonic transducer to generally align the resulting force 30 applied by the ferromagnetic device with the ultrasonic transducer. The ferromagnetic device advantageously defines a spherical outer surface, such as a steel sphere or a spherical magnet, to enable the ferromagnetic device to remain in a generally fixed position relative to a moving component.

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The present invention also provides methods for ultrasonically joining at least one component. In these methods, the component is positioned adjacent the ultrasonic transducer and the magnetic source, such that the ultrasonic transducer and the magnetic source and are on a common side of the component. The ferromagnetic device is provided on an opposite side of the component, and when the magnetic field is provided by the magnetic source, the ferromagnetic device is supported by the magnetic field so that the component is positioned between the ultrasonic transducer and the ferromagnetic device. The ultrasonic transducer concurrently transmits an ultrasonic signal to join the component. The component may be advantageously advanced, relative to the ultrasonic transducer, as the ultrasonic transducer transmits the ultrasonic signal to define a joint along the component.

The present invention, therefore, provides a system and method for conveniently joining at least one component by ultrasonic welding. The magnetic source and ferromagnetic device provide sufficient pressure during the joining process to permit a joint, seam, or the like to be reliably and repeatedly formed. Furthermore, the present invention requires relatively less fixturing and provides more convenient and consistent application of pressure during the joining process than previous techniques.

BRIEF DESCRIPTION OF THE DRAWING

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a side elevational view of an ultrasonic welding apparatus according to one embodiment of the present invention, illustrating the ultrasonic transducer and the magnetic source on a common side of the component and the ferromagnetic device on an opposite side of the component.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein;

rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

With reference to **FIG. 1** an ultrasonic welding apparatus in accordance with one embodiment of the present invention is illustrated. The ultrasonic welding apparatus **10** of **FIG. 1** is illustrated during the joining process of a single thermoplastic component. Specifically, **FIG. 1** illustrates an ultrasonic transducer **12** with a booster **13** and an ultrasonic horn **14** joining a rolled thermoplastic sheet **16**, shown in cross-section, into a tubular body by ultrasonically welding opposed edges of the thermoplastic sheet to define a joint **18**. This application of the ultrasonic welding apparatus **10** of the present invention is representative only and is not intended to limit the present invention to ultrasonic welding of specific materials, shapes, or the like. The ultrasonic welding apparatus of the present invention is advantageously used to join non-ferromagnetic materials. Additionally, the ultrasonic welding apparatus of the present invention may be used to join one or more components to create any type of joint, such as simple lap, butt scarf lap, wall butt lap, or tongue and groove joints to list non-limiting examples.

The ultrasonic transducer **12** illustrated in **FIG. 1** may be the Zonic 20 Universal ultrasonic welder, which is available from Ultrasonic Engineering Ltd. of London, England. The Zonic 20 Universal ultrasonic welder is capable of ultrasonically welding plastics of various dimensions. However, it should be appreciated that the ultrasonic transducer of further embodiments of the present invention may comprise alternative ultrasonic transducers. The ultrasonic transducer **12** of the ultrasonic welding apparatus **10** includes a booster **13** and an ultrasonic horn **14**. The ultrasonic transducer **12** converts electrical energy to ultrasonic energy and transmits an ultrasonic signal comprising mechanical vibrations that are used for the joining process. The booster **13** amplifies the mechanical vibrations produced by the ultrasonic transducer and transfers them to the ultrasonic horn **14**. The ultrasonic horn **14** transfers the mechanical vibrations to the component being joined. The ultrasonic horn **14** typically engages the component **16** being welded to facilitate the transfer of the mechanical vibrations to the component. Further embodiments of the present invention may include ultrasonic transducers that comprise alternative or additional parts or that transfer the mechanical vibrations by alternative techniques.

To provide the requisite pressure on the component 16 during the joining process, the ultrasonic welding apparatus 10 of the present invention includes a magnetic source that provides a magnetic field that attracts a ferromagnetic device toward the magnetic source and thus provides the requisite pressure to the component.

5 For the ultrasonic welding apparatus of FIG. 1, the magnetic source comprises a first electromagnet 20 and a second electromagnet 22 that provide a magnet field to attract the ferromagnetic device 24. The magnetic source is proximate the ultrasonic transducer 12, such that it is on a common side of the component 16 as the ultrasonic transducer, and is on an opposite side of the component from the ferromagnetic device 24. The magnetic source of the embodiment of FIG. 1, which comprises a first electromagnet 20 that is a first distance from a first side 30 of the ultrasonic transducer 12 and a second electromagnet 22 that is a second distance from a second side 32 of the ultrasonic transducer, may be advantageously configured such that the first and second distances are equivalent. The distances may be measured in any direction from any relative reference points, so long as the reference points are commensurate for both electromagnets 20 and 22. By providing electromagnets 20 and 22 that are equally spaced from the ultrasonic transducer 12, and particularly the ultrasonic horn 14, the ultrasonic welding apparatus of the present invention provides a magnetic field with a midplane that coincides with the center of the ultrasonic transducer and ultrasonic horn. Accordingly, the pressure provided by the ferromagnetic device will advantageously be centered on the ultrasonic horn to provide generally uniform pressure to the component during the joining process.

10 Further embodiments of the present invention may provide alternative configurations with magnetic sources comprised of one or more magnets at various positions relative to the ultrasonic transducer, such that the magnetic field is centered or is not centered with respect to the ultrasonic transducer and ultrasonic horn.

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The magnetic source of FIG. 1 comprises two electromagnets 20 and 22. The electromagnets advantageously provide an adjustable magnetic field, such that a change in the magnetic field changes the compressive force or pressure that the ferromagnetic device applies to the component. Accordingly, the present invention provides for precise application of compressive forces on the component being joined. However, further embodiments of the present invention comprise magnetic sources that provide a constant magnetic field, such as by one or more permanent magnets.

Examples of permanent magnets that may comprise the magnetic source include, but are not limited to, standard ceramic magnets, ferrite magnets, or magnets formed of neodymium iron boron, samarium cobalt, or alnico. The magnetic source may also provide adjustable magnetic fields by alternative devices, such as rare earth metal switched devices, as disclosed in U.S. Patent No. 6,180,928, which is assigned to the present assignee, to list one non-limiting example. Still further embodiments of the present invention comprise alternative magnetic sources.

The ferromagnetic device 24 of **FIG. 1** is a magnet that defines a generally spherical outer surface. The ferromagnetic device of further embodiments of the present invention may comprise any ferromagnetic material, such as steel or other metals, to list non-limiting examples, but is advantageously a magnet to provide a relatively strong magnetic coupling between the magnetic source and ferromagnetic device, which further provides a relatively strong compressive force on the composite positioned therebetween. The ferromagnetic device 24 of **FIG. 1** is advantageously a permanent magnet, such as a standard ceramic or ferrite magnet or a magnet formed of neodymium iron boron, samarium cobalt, or alnico, to list non-limiting examples. The ferromagnetic device 24 of the illustrated embodiment also defines a generally spherical outer surface so that the ferromagnetic device may rotate as the component is moved relative to the ultrasonic transducer 12 and/or the magnetic source 20 and 22, such that the ferromagnetic device remains in a generally fixed position relative to a moving component during the joining process. For the component 16 of **FIG. 1**, the rolled sheet of thermoplastic is advanced axially (into or out of the page) to define the joint 18 along a generally axial direction. By providing a ferromagnetic device 24 that is generally spherical, the ferromagnetic device may roll along the inside surface of the rolled sheet to remain in the generally fixed position relative to the moving component so that the ferromagnetic device maintains a generally consistent compressive force on the component at a generally consistent location, relative to the ultrasonic transducer 12 and horn 14.

It should be appreciated that the ferromagnetic device of further embodiments of the present invention may define alternative shapes. The shape of the ferromagnetic device may be customized to suit the particular application for which it will be used. For example, if at least one component is being joined to itself or another component in such a way that a spherical ferromagnetic device would not

provide or maintain compressive force in the desired direction because of the shape of the joint, such as in a lap joint, to list one non-limiting example, the ferromagnetic device may define a shape that conforms more closely to the intended joint configuration. Non-limiting examples of alternative ferromagnetic devices include 5 ferromagnetic devices defining a generally cylindrical outer surface to accommodate a relatively wide joint or a stepped cylindrical outer surface to accommodate a step in at least one component being joined. Furthermore, the diameter or other dimension of the ferromagnetic device may be customized for the particular application.

As previously described, the component 16 of **FIG. 1** is a thermoplastic sheet 10 that has been rolled prior to engaging the ultrasonic welding apparatus 10. Fixturing (not shown) is advantageously provided to maintain the generally cylindrical shape of the component 16 prior to the joining process because the component 16 typically has been elastically deformed and thus will generally return to its un-rolled shape if not restrained. The component 16 of **FIG. 1** is shown in an axial cross-section as the 15 component is being axially advanced relative to the ultrasonic welding apparatus 10. The joining process creates the joint 18 along opposed edges of the component to permanently join the edges and define a generally circular axial cross-section. Components of alternative material or shape, or combinations of components of differing materials and shapes may be joined using the ultrasonic welding apparatus.

20 To ultrasonically join at least one component with the ultrasonic welding apparatus of the present invention, the component 16 is positioned adjacent the ultrasonic transducer 12, such that the ultrasonic transducer and the magnetic source 20 and 22 are on a common side of the component, as representatively shown in **FIG. 1**. Advantageously, the component 16 is positioned such that the portion of the 25 component to be joined, such as the opposed edges of the component of **FIG. 1**, engage the ultrasonic horn 14 of the ultrasonic transducer 12. Additionally, the component may also engage the magnetic source 20 and 22, as also shown in **FIG. 1**. Once the component 16 has been generally positioned adjacent the ultrasonic transducer 12 and magnetic source 20 and 22, the ferromagnetic device 24 is provided 30 on a side of the component that is opposite the ultrasonic transducer and the magnetic source, such that the component is positioned between the ultrasonic transducer and ferromagnetic device. Typically, an operator provides the ferromagnetic device 24 at the appropriate location manually; however, an automated system may alternatively

provide the ferromagnetic device at the predetermined location and time as required. Once the ferromagnetic device 24 has been positioned and the magnetic source 20 and 22 activated so as to produce the magnetic field, the ferromagnetic device 5 advantageously is supported entirely by the magnetic field such that arms and other fixturing are not required to maintain the position of the ferromagnetic device during the joining process. The ferromagnetic device 24 is magnetically attracted to the magnetic source 20 and 22, which is located on an opposite side of the component 16. Accordingly, the ferromagnetic device 24 applies a compressive force on the component 10 because the component is restraining the ferromagnetic device from moving to the magnetic source. Moreover, the engagement of the component by the ultrasonic horn prevents movement of the component in response to the application of compressive force by the ferromagnetic device, thereby trapping the component therebetween so as to be subject to the compressive force. The amount of compressive force the ferromagnetic device 24 applies is directly related to the 15 intensity of the magnetic field applied by the magnetic source, the magnetic properties of the ferromagnetic device, the mass of the ferromagnetic device, and other parameters or properties of the magnetic source and ferromagnetic device.

To join the component 16, the ultrasonic transducer 12 transmits an ultrasonic signal through the ultrasonic horn 14, and the mechanical vibrations induced by the 20 ultrasonic signal causes the material of the component proximate the ultrasonic transducer to soften or melt. The pressure of the compressive force applied by the ferromagnetic device 24 causes the softened or melted material to deform according to the amount and direction of the compressive force. The component 16 is axially advanced, relative to the ultrasonic transducer, at a particular speed that depends upon 25 the component material, the intensity of the mechanical vibrations, and other parameters or properties of the ultrasonic welding apparatus and component. As the component 16 is axially advanced, the softened or melted material that has been joined hardens to form the joint 18. After the component has been joined along the desired axial length of the component 16 and the ultrasonic transducer 12 is powered 30 off, the ferromagnetic device 24 may be removed from the component before the component is disengaged from the ultrasonic device 12 or after the component has been disengaged. When the magnetic source 20 and 22 comprises an electromagnet, as in FIG.1, the applied magnetic field is advantageously reduced or deactivated to

facilitate the removal of the ferromagnetic device. Alternatively, when the magnetic source comprises a permanent magnet, separation of the ferromagnetic device will require a force greater than the attractive force provided by the permanent magnet. Further embodiments of the present invention may comprise alternative techniques for 5 positioning the ultrasonic transducer, magnetic source, and/or ferromagnetic device and for positioning the component, particularly when two or more components are being joined.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which the invention pertains having the 10 benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and 15 not for purposes of limitation.